Chapter 5
Exploring Mixtures and their Separation

Redeveloped Edition | Class 9 Science | IESC Series

Original NCERT content reimagined with everyday Indian life examples, creative exercises, and interdisciplinary insight.

Opening Wonder

It is 7 a.m. Your mother is making chai. She drops in tea leaves, sugar, milk and water, lets it boil, and then pours it through a small metal strainer into your cup. The tea leaves stay behind in the strainer; the golden-brown liquid flows into the cup. Nobody taught her the word **filtration** — she has done this ten thousand times without ever calling it that.

A few hours later, the monsoon clouds burst over your colony. Water gushes down the street, brown and cloudy with mud. By evening, if a bucket of that water has been standing undisturbed, you notice the mud has settled at the bottom and the water on top looks almost clear — but not quite. Meanwhile, the milk in your fridge never does this, no matter how many days it sits there.

And if you have ever watched your grandmother make **mishri** (rock candy) from a sugar solution left to cool slowly, or watched a lab technician draw your blood for a test and later separate it into a straw-coloured liquid on top and red cells below — you have already witnessed real chemistry happening in front of you, unnamed.

Why does mud settle but milk doesn't? Why does a metal strainer catch tea leaves but not sugar? Why does a solution turn into crystals when it cools? This chapter is about the science of mixtures — how they are classified, how their hidden properties (particle size, solubility, boiling point, density) decide how they behave, and how humans have engineered clever techniques over centuries to pull mixtures apart into their pure components. From sugar factories to malaria test kits, from perfume workshops in Kannauj to your own kitchen sink, separating mixtures is one of the most practically important skills in all of science.

5.1 How Can We Classify Mixtures?

Take a well-stirred glass of sugar syrup (sherbet). The first sip and the last sip taste equally sweet — the composition is uniform throughout. Such a mixture, with the same composition at every point, is called a **homogeneous mixture**, or a **solution**. Vinegar (acetic acid in water), soda (carbon dioxide dissolved in water), and sugar syrup are all homogeneous mixtures — you cannot see the individual components, and they never separate on their own.

Now stir a spoon of sand into a glass of water. Even while stirring, you can clearly see individual sand grains suspended in the liquid, and if you leave the glass alone, the sand settles to the bottom within minutes. This non-uniform mixture, where

components remain distinguishable and often separate out over time, is called a **heterogeneous mixture**. Oil and water, mixed and shaken, form a heterogeneous mixture too — within seconds of stopping the shaking, you can already see two layers beginning to reappear.

Everyday Connection — Your Kitchen Is a Mixtures Laboratory

Look at your kitchen shelf right now, mentally: **salt water** used to soak rice is homogeneous. **Besan (gram flour) stirred into water** for a batter is heterogeneous — the flour never fully dissolves, it stays suspended and settles if left alone. **Buttermilk (chaas)** looks uniform but is actually a colloid (more on this soon). **Achar (pickle) oil floating over the masala and vinegar** is a heterogeneous mixture of immiscible liquids.

Next time you cook, ask yourself: if I stop stirring and wait five minutes, will this mixture look the same everywhere, or will something settle, rise, or separate? That single question is the entire basis of Section 5.1.

Activity 5.1 — Redeveloped: Classify Three Kitchen Mixtures

Original book version: Groups prepare salt–water, chalk powder–water, and milk–water mixtures in beakers, shine a laser through them, and filter each.

Everyday Version: Work in three groups, using kitchen ingredients instead of lab chemicals.

Group A: Dissolve one spoon of **sugar** in 50 mL of water and stir well.

Group B: Mix one spoon of **besan (gram flour)** in 50 mL of water and stir well.

Group C: Add a few drops of **milk** to 50 mL of water and stir well.

Steps: (1) Note whether particles are visible in each. (2) Shine a laser pointer or a strong torch beam through each glass from the side — under adult supervision, never look into the beam directly — and note whether the light's path is visible. (3) Filter each mixture through a clean cotton cloth or filter paper and check for a residue. (4) Predict what each mixture will look like if left undisturbed overnight.

What you should find: the sugar solution shows no visible particles, no light path, and leaves no residue — a true homogeneous solution. The besan mixture shows visible particles, may leave a residue on filtering, and will settle with time — a heterogeneous suspension. The milk mixture shows no visible particles and leaves no residue on ordinary filter paper, yet the light beam becomes visible as it passes through — this is neither A nor B. It is a third category altogether, called a **colloid**, which you will meet properly in Section 5.4.4.

5.2 Solutions

A solution is prepared when a **solute** (the substance that gets dissolved — sugar) is mixed with a **solvent** (the substance that does the dissolving — water). But *how much* solute goes into *how much* solvent matters enormously. Two cups of tea made

by the same person, on the same day, with slightly different amounts of sugar, are technically different solutions — one is sweeter, i.e., more **concentrated**, than the other.

5.2.1 Concentration of a Solution

Every packet of **Oral Rehydration Solution (ORS)** you have ever mixed with water at home follows a strict recipe: a fixed mass of salts and sugar dissolved in exactly one litre of clean water. Add less water, and the solution becomes too concentrated — potentially harmful, especially for a dehydrated child. Add more water, and it becomes too dilute to work. **You cannot freely change the proportions and still call it ORS.** The amount of solute dissolved in a given amount of solvent (or solution) is called the **concentration** of the solution.

Farmers spraying pesticide face the same constraint: too little pesticide in the water fails to protect the crop; too much can damage the crop, the soil, and the people who eat the produce later. Getting the *proportion* right — not just adding more or less at random — is the essential skill in every one of these situations.

> **Meet a Scientist — Dilip Mahalanabis and the ORS Revolution**
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> **Dilip Mahalanabis** (1934–2022) was an Indian paediatrician working in refugee camps in West Bengal during the early 1970s, at a time when cholera and severe diarrhoea were killing enormous numbers of people, especially children, through dehydration. Intravenous fluids were scarce and needed trained staff to administer. Mahalanabis helped refine and popularise a simple **Oral Rehydration Solution** — a precisely proportioned mixture of salt, sugar, and water that could be drunk rather than injected.
>
> The key insight was entirely about concentration: get the ratio of salts and sugar to water exactly right, and the intestine absorbs the fluid efficiently even during severe diarrhoea. Get the ratio wrong, and it does not work — or can even cause harm. The World Health Organization later called ORS possibly the most important medical advance of the twentieth century. It has saved tens of millions of lives, most of them children, and it is still sold in every Indian chemist shop today for a few rupees a packet.

5.2.2 How Do We Express Concentration?

There are several ways to express concentration as a percentage. The three you need to know well are described below, each suited to a different everyday situation.

A. Mass by Mass Percentage (% m/m or % w/w)

This tells us how many grams of solute are present in 100 g of the total solution:

$$\text{Mass by mass percentage} = (\text{Mass of solute} \div \text{Mass of solution}) \times 100$$

This method is used for both homogeneous and heterogeneous mixtures — for example, to label how much salt, sugar, or protein is present in packaged foods, or in a heterogeneous mixture like a spice masala blend or milk powder.

> **Worked Example 5.1 — Redeveloped: Roadside Nimbu-Paani**

(Lemonade)

Original book version: 10 g of salt dissolved in 90 g of water; find the % m/m.

Everyday Version: A roadside vendor makes a glass of nimbu-paani by dissolving 15 g of sugar in 135 g of water (before adding lemon juice). What is the mass by mass percentage of sugar in this sugar–water mixture?

Answer: Mass of solute (sugar) = 15 g. Mass of solvent (water) = 135 g. Total mass of solution = 15 + 135 = 150 g.

Mass by mass percentage = (15 g ÷ 150 g) × 100 = **10% m/m**.

Creative Spark : If the vendor wants a sweeter glass at 15% m/m using the same 135 g of water, how much extra sugar must be added? (Hint: let the new mass of sugar be x, and solve x ÷ (x + 135) × 100 = 15.)

B. Mass by Volume Percentage (% m/v or % w/v)

This is used when it is easier to measure a *volume* of liquid than to weigh it — common in medicines and laboratories. It tells us how many grams of solute are present in 100 mL of solution:

Mass by volume percentage = (Mass of solute ÷ Volume of solution) × 100

Worked Example 5.2 — Redeveloped: Glucon-D After Cricket Practice

Original book version: 5 g of glucose dissolved to make 100 mL of solution; find the % m/v.

Everyday Version: After a hot evening of gully cricket, you mix 5 g of Glucon-D (glucose powder) into water to make 100 mL of an energy drink. What is its concentration in mass by volume percentage?

Answer: Mass of glucose (solute) = 5 g. Volume of solution = 100 mL.

Mass by volume percentage = (5 g ÷ 100 mL) × 100 = **5% m/v** — coincidentally, this is exactly the concentration doctors use for the glucose drips given in hospitals.

C. Volume by Volume Percentage (% v/v)

This is used when two miscible liquids (liquids that mix completely into one phase, like water and vinegar) are combined. It tells us how many millilitres of solute are present in 100 mL of solution:

Volume by volume percentage = (Volume of solute ÷ Volume of solution) × 100

Worked Example 5.3 — Redeveloped: Diluting Phenyl or Dettol for Mopping

Original book version: 1 mL of liquid pesticide mixed with water to make 100 mL of pesticide spray; find % v/v.

Everyday Version: The instructions on a bottle of floor-cleaning phenyl say to mix 20 mL of concentrated phenyl with water to make 500 mL of mopping

solution. What is the % v/v of phenyl in the solution?

Answer: Volume of solute (phenyl) = 20 mL. Total volume of solution = 500 mL.

Volume by volume percentage = (20 mL ÷ 500 mL) × 100 = **4% v/v**.

Pause and Think: Antiseptic liquids like Dettol and Savlon carry very specific dilution instructions on the bottle for different uses — wound cleaning needs a much more dilute solution than floor mopping. Using too concentrated a solution on skin can cause irritation or burns. Precision in % v/v is not just a classroom exercise — it is printed on the label for your safety.

Everyday Connection — Reading the Fine Print on Your Snack Packet

Next time you open a packet of chips, biscuits, or a juice carton, look at the nutrition label. It usually reports quantities like "sodium: 400 mg per 100 g" — this is nothing but a mass by mass percentage in disguise (0.4% m/m sodium). Saline drips used in hospitals are labelled 0.9% m/v sodium chloride — meaning 0.9 g of common salt in every 100 mL of the solution — carefully matched to the salt concentration of human blood so that it does not disturb the body's cells.

5.2.3 Solubility of Substances

The maximum amount of solute that can dissolve in a fixed quantity of solvent (100 g or 100 mL) at a given temperature is called its **solubility** at that temperature. A solution that cannot dissolve any more solute at that temperature is called a **saturated solution**. Temperature matters because the solubility of most solid solutes in a liquid solvent **increases** with temperature, while the solubility of gases dissolved in liquids generally **decreases** as temperature rises.

Everyday Connection — Why Your Cold Drink Goes Flat Faster on a Hot Day

Carbon dioxide gas dissolved in a soft drink is what gives it its fizz. Because gas solubility falls as temperature rises, a chilled cold drink holds far more dissolved CO_2 than the same bottle left out in the Indian summer sun — which is exactly why an unrefrigerated bottle goes flat noticeably faster, and why a warm glass of soda fizzes so aggressively the moment you open it: the excess dissolved gas is rushing to escape now that the liquid can no longer hold it in solution at that temperature.

Activity 5.2 — Reading a Solubility Curve

A graph of solubility (grams per 100 g of water) against temperature is called a **solubility curve**. Two substances, compound 'A' and compound 'B', dissolved in water, might show very different curves — one rising sharply with

temperature, another staying almost flat.

Try this: if compound A's solubility rises from about 60 g/100 g water at 20 °C to about 110 g/100 g water at 60 °C, while compound B's solubility stays close to 240–290 g/100 g water across the same range, which compound's solubility is *more sensitive* to temperature? Which one would be a better choice for the crystallisation technique you are about to learn in Section 5.3.1, and why?

5.3 Methods of Separation of Homogeneous Mixtures

5.3.1 Crystallization

If you prepare a saturated solution of a solute at a high temperature and then cool it gradually, the solvent can no longer hold as much dissolved solute at the lower temperature (since solubility usually falls as temperature drops). The excess solute separates out — often as beautifully regular, geometric solids called **crystals**. This process, carried out deliberately in a laboratory or a factory, is called **crystallization**. It is used to separate two dissolved solids when one is present in a much smaller quantity than the other, and it is also widely used to **purify** solids, since impurities are typically left behind in the remaining liquid (the mother liquor) rather than joining the crystal lattice.

Everyday Connection — Mishri, Rock Salt and the Great Indian Salt Pans

Mishri (rock candy), sold outside temples and used to sweeten *panjiri* and prasad, is made exactly this way — a hot, saturated sugar solution is allowed to cool very slowly, undisturbed, over days, so that large, clear sugar crystals form on strings dipped into the syrup.

On a much larger scale, India's coastal salt pans (in Gujarat, Tamil Nadu, and elsewhere) use crystallization every single day: shallow ponds of seawater are left in the sun, water evaporates, the solution becomes saturated with common salt, and salt crystals form and are raked out. This is the same principle behind the traditional **panga** and **karkatch** salt-making methods practised for centuries along India's coasts — concentrating brine until crystals separate out.

Activity 5.3 — Redeveloped: Growing Copper Sulfate Crystals at Home/Lab

Original book version: Prepare a saturated copper sulfate solution, filter it hot, cool it slowly, and collect crystals.

Everyday Version (kept close to the original, since this is genuine lab chemistry): Take 1 g of copper sulfate (blue vitriol) in a 100 mL beaker with 25 mL of water and a drop of dilute sulfuric acid (added only by a teacher/adult —

copper sulfate is toxic, handle with gloves and never touch it bare-handed). Gently heat in a water bath, stirring, and keep adding copper sulfate until the solution is saturated. Filter the hot solution to remove insoluble impurities, collect the filtrate, and let it cool slowly and undisturbed. Filter out and dry the crystals that form.

Why this mirrors the mishri and salt-pan examples above: in every case — copper sulfate in a beaker, sugar syrup on a string, or brine in a coastal salt pan — the underlying principle is identical: reduce a saturated solution's capacity to hold solute (by cooling, or by evaporating the solvent), and pure solid crystallises out.

Think as a Scientist — Fast Cooling vs Slow Cooling

If a hot, saturated copper sulfate solution is cooled **rapidly** in ice-cold water, it forms many small, poorly-formed crystals. If it is cooled **slowly** at room temperature, it forms fewer, larger, well-shaped, shiny crystals.

Design your own test: split a freshly prepared hot saturated solution into two identical beakers. Cool one rapidly in an ice bath and let the other cool slowly on a shelf, undisturbed, for the same total time. Compare the crystals under a magnifying glass. What does this suggest about why mishri-makers dip their strings into syrup and then wait patiently for days, rather than rushing the process in a refrigerator?

Ready to Go Beyond — Crystals Made by Nature Itself

Crystallization is not only something humans do in a lab or a factory — it happens in nature over thousands or millions of years. **Mawsmai Cave** near Sohra (Cherrapunji) in Meghalaya is famous for its natural mineral crystal formations, built up as mineral-rich water slowly evaporated or changed temperature over long periods. **Quartz**, one of the most common crystals on Earth, forms the same way, deep within rock. Even the frost patterns you may have seen on a cold glass window, or a snowflake (if you have ever travelled to the Himalayas in winter), are crystals — this time of water, formed as water vapour turns directly into ice.

When a solvent evaporates completely to leave a solute behind (like salt from seawater), the solvent itself is lost to the air. But what if you want to **recover the solvent** too — for example, to separate two miscible liquids like acetone and water? Evaporation alone will not do this cleanly, because both liquids would evaporate together. We need a technique based on a different property: **boiling point**.

5.3.2 Distillation

A homogeneous mixture of two miscible liquids can be separated by heating the mixture until the liquid with the **lower boiling point** vaporises first. This vapour is then cooled in a condenser, turning it back into liquid — a process called

distillation. It works well when the two liquids' boiling points differ by at least about 25 °C, and it can also be used to recover a pure liquid from a solution containing a dissolved solid (such as recovering water from salt water).

During distillation, vapour from the lower-boiling liquid passes into a water- or air-cooled condenser, where it turns back into a pure liquid called the **distillate**, collected separately, while the remaining liquid (or dissolved solid) stays behind in the distillation flask. A mixture of acetone (boiling point ≈ 56 °C) and water (boiling point ≈ 100 °C) is a classic example — the 44 °C gap between their boiling points is comfortably large enough for clean separation by distillation.

India's Scientific Contributions — Mitti ka Ittar, the Perfume of the First Rain

That unmistakable earthy smell rising from dry ground after the first monsoon shower has a name — **petrichor** — and in Kannauj, Uttar Pradesh (known as the perfume capital of India), artisans have captured this exact fragrance in a traditional perfume called **Mitti ka Ittar**, using a centuries-old distillation method called the **Deg-Bhapka** technique. Vapours carrying fragrance compounds are distilled off, condensed, and collected in sandalwood oil, preserving the smell of rain itself in a small glass bottle. Kannauj's Fragrance and Flavour Development Centre continues to extract fragrance and flavour compounds from flowers and plants using these same principles today, and supports farmers growing fragrance crops.

Ready to Go Beyond — Fractional Distillation and Your LPG Cylinder

A petroleum refinery separates crude oil — a complex mixture of many hydrocarbon liquids and gases with boiling points close together (often less than 25 °C apart) — using **fractional distillation**, a refined version of ordinary distillation designed for closely-spaced boiling points. This is how crude oil, pumped out of the Earth, becomes the separate, useful products in your daily life: petroleum gas (compressed and sold to your home as **LPG cylinders**), petrol and diesel for vehicles, aviation fuel (kerosene) for the flights overhead, lubricating oil for machines, and bitumen for the roads you walk and cycle on. Every time your family gets an LPG cylinder refilled, you are holding the lightest fraction separated out of crude oil by fractional distillation.

5.3.3 Paper Chromatography

Have you noticed that when a raindrop falls on writing done with a black sketch pen, the black ink spreads out into several different colours? This method of separating the components of a mixture — based on how differently each component interacts with a solvent and with paper — is called **paper chromatography**. The word comes from the Greek *chroma* (colour) and *graphein* (to write) — literally 'writing with colour' — because it was first used to separate coloured dyes.

Activity 5.5 — Redeveloped: Chasing the Colours in a Monsoon-Smudged Notebook

Original book version: Draw a pencil line 2 cm from the bottom of a chromatography/filter paper strip, mark a black sketch-pen ink spot on it, dip the strip's lower end (below the spot) into a thin layer of water in a jar, and watch the colours separate as water rises.

Everyday Version: You have probably seen a school notebook get caught in monsoon rain, with a gel-pen or sketch-pen answer smudging into a rainbow of colours along the wet page — that is chromatography happening by accident. Recreate it on purpose: use a black sketch pen (or a food colour like green, orange, or the coloured coating on fennel-seed mouth fresheners, *saunf*) as your ink spot, and try water, and separately a 2% m/v salt solution, as your solvent.

What to observe: as the solvent rises up the strip by capillary action, it carries the ink's components upward at different rates — components that cling more weakly to the paper (and dissolve more easily in the solvent) travel further and faster than components that cling more strongly. What was one 'black' spot becomes a ladder of separate coloured bands.

Extend it: try the same technique on a crushed, alcohol-soaked spinach leaf, or flower petals, to separate the different plant pigments hidden inside a leaf that looks uniformly green to your eye.

Thread of Curiosity — Are Autumn Leaves Hiding Other Colours All Along?

Investigate whether a red or brown leaf (common in many Indian trees during the dry season) still secretly contains green chlorophyll pigment, using paper chromatography on a crushed leaf extract. Chlorophyll usually breaks down faster than other pigments as a leaf ages, revealing the yellow, orange, and red pigments that were present all along, simply masked by the dominant green.

5.4 How Can We Separate the Components of Heterogeneous Mixtures?

5.4.1 Separation of Two Immiscible Liquids

Pour water into a container that already has oil in it, and the two never mix — they form distinct layers instead. Liquids that behave this way are called **immiscible liquids**. Mustard oil and water, like most cooking oils and water, are immiscible; oil (being less dense) floats above water. A **separating funnel** exploits exactly this density difference: the denser liquid (water) is drained from the bottom through a stopcock, leaving the lighter liquid (oil) behind in the funnel.

Everyday Connection — Achar Jars and Washing-Up Water

Open a jar of homemade pickle (achar) and you will usually find a layer of

mustard oil sitting on top of the masala and brine below — the same immiscibility at work that a separating funnel exploits in a lab. Similarly, when you wash oily kadhais and pans, the greasy water you pour out often separates into a thin oily film on top if left standing, which is part of why plain water alone struggles to clean oil off utensils — soap or detergent is needed to break the oil into tiny, water-dispersible droplets, since oil and water simply refuse to mix on their own.

Gases, on the other hand, mix freely and completely with each other in almost every case, since gas particles move independently in all directions — a mixture of hydrogen and oxygen (used as rocket fuel) is homogeneous. Heterogeneous mixtures *with* a gas usually involve solid or liquid particles suspended in the gas: **smoke** (solid particles in air), **fog** (tiny liquid water droplets in air), and ordinary **dust** in the air are all examples.

5.4.2 Sublimation

Some solids, on heating, change directly into vapour without ever passing through the liquid state — this is called **sublimation**. On cooling, the vapour changes directly back into a solid without becoming a liquid first — this is called **deposition**. Because not every solid in a mixture sublimes, this becomes a powerful separation technique: heat a mixture of a sublimable solid and a non-sublimable solid, and only the sublimable one leaves as vapour, which can then be re-deposited as a pure solid elsewhere.

Everyday Connection — Camphor at the Temple, Mothballs in the Cupboard

The camphor (kapoor) tablet lit during **aarti** at a temple or a home puja does not melt into a liquid pool before burning away — it turns directly into fragrant white vapour, which is why the smoke smells so strongly of camphor: it is literally sublimed camphor in the air. **Naphthalene mothballs**, kept in almirahs to protect woollens and sarees from silverfish and moths, slowly shrink over months for exactly the same reason — they sublime steadily at room temperature, releasing vapour that repels insects, until eventually nothing is left behind.

Activity 5.7 — Redeveloped: Separating Camphor (or Naphthalene) from Sand

Original book version: Heat a mixture of crushed camphor and sand in a china dish under an inverted, cotton-plugged glass funnel; camphor deposits as solid white crystals on the inner wall of the funnel while sand stays behind.

Everyday Version: This is best performed exactly as in the lab, using either camphor tablets (as sold for puja) or naphthalene balls, crushed and mixed with sand. Heat gently; observe white solid deposits forming on the cool inner wall of the inverted funnel while the sand remains, undisturbed, in the dish below.

Real-world extension: industrially, solid carbon dioxide (dry ice), used to keep ice cream and vaccines cold during transport across India's hot climate, sublimes directly into CO_2 gas rather than melting into a puddle — which is exactly why it is prized as a 'dry' coolant that leaves no liquid mess behind.

Can one metal dissolve in another? Not at room temperature — but metals melted at very high temperatures can be mixed to form a solution, which solidifies on cooling into a new, homogeneous material called an **alloy**. Physical separation methods cannot pull an alloy's metals apart; alloys are deliberately engineered to be stronger, harder, or more corrosion-resistant than their component metals alone.

Everyday Connection — The Alloys in Your Own Life

Brass (about 80% copper, 20% zinc) is the golden-yellow metal in temple bells, idols, and traditional cooking vessels. **Bronze** (about 80% copper, 20% tin) is used for statues and medals. **Stainless steel** — the alloy of your kitchen utensils, water bottles, and railway carriages — is mostly iron mixed with chromium (16–18%), nickel (10–14%), a little carbon, and molybdenum, engineered specifically to resist the rusting that plain iron suffers so badly in India's humid climate. Even the gold jewellery bought during Diwali or a wedding is rarely pure — 22-karat gold is an alloy of about 92% gold with copper and/or silver added for strength, since pure (24-karat) gold is too soft to hold its shape in fine jewellery.

5.4.3 Suspensions

In a mixture like sand stirred into water, no amount of stirring makes the sand particles disappear from view — unlike in a true solution, where solute particles are never visible, however carefully you look. A heterogeneous mixture in which solid particles remain visibly suspended throughout the liquid, without dissolving, is called a **suspension**. Suspension particles are larger than solution particles and are visible to the naked eye — sawdust in water and tea leaves in water are everyday suspensions.

If muddy monsoon water is left undisturbed, heavier mud particles settle at the bottom, but the water often still looks cloudy — the finer particles remain suspended. Filtering through cloth or filter paper removes only the larger particles; very fine suspended matter frequently passes straight through. When settling and simple filtration are not enough, two further techniques come into play: **centrifugation** and **coagulation**.

A. Centrifugation

Cross arms with a partner, hold hands, and spin around together fast — you feel a strong outward pull. This is the same **centrifugal force** (the outward force experienced by anything moving in a circular path) that a laboratory centrifuge uses: a mixture is spun in a tube at very high speed, and the denser, heavier particles are forced outward and downward to the bottom of the tube, while the lighter liquid stays near the top.

Everyday Connection — Your Washing Machine Is a Centrifuge

The 'spin' cycle at the end of a washing machine's wash is literally centrifugation: the drum spins clothes at high speed, and centrifugal force flings water outward through small holes in the drum, leaving clothes damp rather than dripping. It is the exact same physical principle that a diagnostic lab uses to spin a blood sample into layers of plasma, white blood cells and platelets, and red blood cells — just applied to fabric and water instead of blood.

Bridging Science and Society — The Paperfuge

A full laboratory centrifuge needs electricity, which is not always reliably available in remote or rural clinics. Inspired by a simple spinning toy, researchers built the **paperfuge** — a cheap, hand-powered device made from cardboard, string, and a handle — that spins blood samples fast enough to separate their components without any electricity at all, enabling diagnosis of diseases like **malaria** and anaemia in places a powered centrifuge cannot reach. It is a striking example of how a children's toy's physics can be repurposed to save lives in under-resourced health settings.

Activity 5.8 — Redeveloped: Build a Model Centrifuge

Original book version: Build a paperfuge-style model from a cardboard disc and thick thread, and observe how heavier particles move outward when spun.

Everyday Version: Build the same cardboard-and-string model at home. Instead of blood (which needs a lab), test it with a dilute mixture you can make safely, such as a little chalk-powder-in-water suspension, and observe how the spinning motion pushes the heavier suspended particles outward and away from the centre. Which mixture from your own kitchen would you like to try separating this way?

B. Coagulation

Powdered alum (**fitkari**), a white crystalline substance long used in Indian households for water purification, can be added to muddy water to make the very fine suspended particles clump together into larger flakes — a process called **coagulation**, with alum acting as the **coagulant**. These larger clumps then settle by gravity (sedimentation) and can be removed by decantation or filtration.

Everyday Connection — Fitkari, RO Purifiers and Paneer

Many Indian households and municipal water treatment plants still use alum to clarify muddy water drawn from rivers, tanks, or wells before it goes through further filtration and disinfection — an old, low-cost technique that remains genuinely effective today. On a kitchen scale, **paneer** is made through a related process: adding an acid (lemon juice or vinegar) to hot milk causes the milk proteins to coagulate and clump together into soft curds, which are then strained through muslin cloth — separating solid paneer from the liquid whey.

5.4.4 Colloids

Blood can be separated into layers by centrifugation, and it can also coagulate — so is it a suspension? Yet its cells cannot be seen with the naked eye — so is it a solution? Blood is neither. It belongs to a third category: a **colloid**. Milk, tomato sauce, shaving foam, and ice cream are everyday colloids.

Solutions, suspensions, and colloids differ mainly in **particle size**. Solute particles in a true solution are smaller than 1 nanometre in diameter — far too small to see or to scatter light. Colloidal particles are larger, between 1 and 1000 nanometres, small enough to stay permanently and uniformly dispersed (unlike a suspension, colloid particles do **not** settle over time), yet large enough to scatter light. Suspension particles are larger still — over 1000 nanometres — visible to the naked eye and prone to settling under gravity.

> **Thread of Curiosity — Emulsions: Colloids Where Both Phases Are Liquid**
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> When both the dispersed phase and the dispersion medium of a colloid are liquids, the colloid is called an **emulsion**. **Milk** and vanishing creams are oil-in-water emulsions (tiny droplets of oil or fat dispersed in water); **butter**, body lotions, and cold creams are water-in-oil emulsions. Many liquid medicines are prepared as emulsions specifically so they mix smoothly with water and feel less greasy on the tongue. **Try it yourself:** shake a few drops of cooking oil vigorously with water containing a few drops of soap solution — the soap acts as an emulsifying agent (much like the proteins that naturally stabilise milk and butter), keeping the oil droplets from re-merging and separating back out.

5.5 Tyndall Effect

Recall the laser-beam test from Activity 5.1: the light's path was invisible passing through the true solution, but clearly visible passing through the suspension and through the milk-and-water colloid, even though the colloid looked just as clear and uniform as the solution to the naked eye. This scattering of light by dispersed particles is called the **Tyndall effect**, named after the scientist **John Tyndall**, who studied how particles scatter light. It occurs when light passes through a colloid or a suspension, but not through a true, transparent solution — because only colloidal and suspension-sized particles are large enough to scatter visible light noticeably; true solution particles are far too small.

> **Meet a Scientist — John Tyndall and the Blue of the Sky**
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> **John Tyndall** (1820–1893), an Irish physicist, showed experimentally in the 1860s that fine particles suspended in air or liquid scatter light passing through them, and that shorter (bluer) wavelengths of light scatter more strongly than longer (redder) wavelengths off very small particles. This work helped explain, among other things, why the sky appears blue — sunlight scattering off

molecules and fine particles in the atmosphere. His name is now permanently attached to this phenomenon: the Tyndall effect.

Thread of Curiosity — C. V. Raman and the Physics of Scattered Light

Tyndall studied how particles scatter light without changing its colour. Decades later, Indian physicist **C. V. Raman** discovered something subtler in 1928: when light passes through a transparent substance, a tiny fraction of it scatters with its *wavelength changed*, carrying a fingerprint of the molecules it passed through. This discovery, the **Raman effect**, won him the Nobel Prize in Physics in 1930 — the first Nobel Prize in the sciences won by an Asian for work done entirely in Asia — and Raman spectroscopy remains a standard tool today for identifying unknown chemical substances, from art forgery detection to pharmaceutical quality checks.

Everyday Connection — Headlights in Fog, Stadium Floodlights, and Sunlight Through a Dusty Room

You have almost certainly seen the Tyndall effect without naming it: car headlights lighting up a beam through fog or dust on a highway; floodlight beams becoming visible cones of light in a dusty or misty stadium at night; or a shaft of sunlight through a small gap in curtains, suddenly revealing thousands of dust particles floating in what looked like completely clear air. In every one of these cases, particles too small to see individually are still large enough, collectively, to scatter light and make its path visible — and that is precisely why cities thick with smoke and dust particles often look **hazy**: the suspended particulate matter is scattering sunlight throughout the whole sky, the very same effect happening on a city-wide scale.

Activity 5.9 — Complete the Comparison Table

Before moving to the summary, test yourself: for each of Solution, Suspension, and Colloid, can you state from memory (i) whether it is homogeneous or heterogeneous, (ii) typical particle size, (iii) whether particles are visible, (iv) whether it can be separated by ordinary filtration, (v) whether it settles on standing, and (vi) whether it shows the Tyndall effect? Write out the full 3×6 comparison before checking it against Section 5.4.4 and Section 5.5 above.

Separation is not always simple — try, for instance, to separate all the individual ingredients out of a glass of nimbu-paani once they are mixed, and you will quickly appreciate why chemists spend entire careers developing new separation techniques. Separation also happens continuously in nature and inside your own body: your **kidneys** filter waste products out of your blood every minute of every day. On a larger scale, treating **sewage water** before releasing it into rivers involves sedimentation, coagulation, and filtration in sequence — the very same techniques you have just learned — so that the cleaned water can be safely reused for flushing

or irrigation. Sorting household waste into dry waste (recyclable plastic, paper, glass, metal) and wet waste (compostable food scraps) is separation too, and researchers are now developing ways to recover valuable materials like lithium from old mobile phone and laptop batteries — proving that the science of separating mixtures is central to building a cleaner, more sustainable future.

Chapter Summary

Concept	Core idea	Everyday example
Homogeneous mixture / solution	Uniform composition throughout; particles too small to see or filter out	Sugar syrup, vinegar, soda
Heterogeneous mixture	Non-uniform composition; components remain distinguishable	Sand in water, oil and water, muddy water
Concentration (% m/m, % m/v, % v/v)	Amount of solute relative to solvent or solution, expressed as a percentage	ORS packets, saline drips, diluted phenyl/Dettol
Solubility	Maximum solute a fixed amount of solvent can dissolve at a given temperature	Sugar dissolving faster in hot tea than cold water
Crystallization	Cooling a saturated solution to deposit pure solid crystals	Mishri, coastal salt-pan salt production
Distillation	Separating miscible liquids using differences in boiling point	Recovering acetone/water; Kannauj's Mitti ka Ittar
Fractional distillation	Separating liquids with closely-spaced boiling points	Petroleum refining into LPG, petrol, diesel
Paper chromatography	Separating mixture components by differing movement through paper with a solvent	Ink spreading in rain, separating leaf pigments
Separating funnel	Separating immiscible liquids using density difference	Mustard oil from water, achar oil layer
Sublimation / deposition	Solid to vapour (and back) without passing through the liquid state	Camphor at puja, naphthalene mothballs, dry ice
Alloys	Homogeneous mixtures of metals, not separable by physical means	Brass, bronze, stainless steel, 22K gold jewellery
Suspension	Heterogeneous mixture with large, visible, settling particles	Muddy water, sawdust in water, tea leaves in water

Concept	Core idea	Everyday example
Centrifugation	Rapid spinning to separate particles by density	Washing machine spin cycle, blood test separation, paperfuge
Coagulation	Adding a coagulant to clump fine particles together for settling	Alum (fitkari) in water purification, paneer-making
Colloid	Intermediate particle size; does not settle; scatters light	Milk, blood, ice cream, shaving foam
Tyndall effect	Scattering of light by colloidal or suspension particles	Headlight beams in fog, sunlight through dusty air

Revise, Reflect, Refine — Exercises

Basic Recall

1. Differentiate between a homogeneous and a heterogeneous mixture using one example each from your own kitchen.
2. Define concentration of a solution. Name the three ways of expressing concentration as a percentage, and state one everyday situation where each is used.
3. What is the Tyndall effect? Name one scientist associated with it and give two everyday examples where you can observe it.

Apply & Think

1. A bottle of floor cleaner says "mix 25 mL of concentrate with water to make 1 litre of solution." Calculate the % v/v of the concentrate. If your family accidentally uses 50 mL of concentrate for the same 1 litre, will the resulting % v/v be higher or lower, and is this necessarily safe?
2. Your friend says, "Milk is just a solution of fat in water, like sugar in water." Using what you have learned about particle size, visibility, filtration, settling, and the Tyndall effect, write a paragraph explaining why this is scientifically inaccurate.
3. You want to recover clean drinking water from a small quantity of muddy river water while on a school trek, using only basic equipment (a pot, a lid, a cup, and a fire). Describe a method based on a technique from Section 5.3.2, and explain why it would work.

Creative Design Challenges

1. **The Household Mixture Audit:** Walk through your home for ten minutes and list five mixtures you find (foods, cleaning products, cosmetics). Classify each as a solution, suspension, or colloid, and justify your classification using at least two properties from Table-style reasoning (particle size, filtration, settling, Tyndall effect).
2. **Design a Purification Chain:** A tank of muddy pond water needs to be made fit for washing clothes (not drinking). Design a sequence of at least three separation techniques from this chapter, in the correct order, explaining what each step removes and why that order makes sense.

3. **The Alloy Detective:** Choose one metal object from your home (a steel spoon, a brass idol, a gold ring, a bronze medal). Research what alloy it is made of, what elements/metals it contains, and why that particular combination was chosen over the pure metal.
4. **AI Creative Spark — The Future Separation Challenge:** Imagine you are an engineer in 2050 tasked with separating microplastics from ocean water at a massive scale. Based on the separation principles in this chapter (size, density, solubility, boiling point, sublimation), propose a plausible multi-step process. What new technology might be needed that does not exist today?

Journey Beyond — Going Deeper

Challenge A: Demonstrate the Tyndall Effect at Home

Using a torch or laser pointer (under adult supervision — never look directly into the beam) and everyday colloids such as milk-and-water, a dilute soap solution, or fine dust stirred into water, design a short series of demonstrations comparing how clearly the light beam is visible in a true solution versus a colloid. Record your observations with photographs if possible.

Challenge B: Grow and Compare Crystals

Grow crystals of two or three different substances available safely at home (common salt, sugar, alum/fitkari, Epsom salt if available) using the slow-cooling or slow-evaporation method from Section 5.3.1. Examine them under a magnifying glass and compare their colour, shape, and size. Which substance produced the most well-formed crystals, and can you relate this to its solubility curve?

Challenge C: Chromatography of Everyday Colours

Use paper chromatography to investigate how many separate coloured components are hidden inside a single food colour (green, orange, or brown), a coloured mouth-freshener coating (saunf/fennel seeds), or Holi colour powder. Try more than one solvent (water, then a water-alcohol mixture) if the colour does not separate well in water alone, and record how many distinct bands you can identify each time.

Happy Exploring! The next time you make chai, wash the dishes, or watch the monsoon rain turn a street to mud, you will see mixtures — and the science of pulling them apart — everywhere around you.